

## Life Prediction Methodology for Ceramic Matrix Composites

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MSFC along with the expertise of LeRC personnel began a program in FY95 with the overall goal of developing, codifying and validating a life prediction methodology for ceramic matrix composite (CMC) engine components. The critical damage mechanisms are being investigated through a large number of interrupted high-temperature cyclic and monotonic tests. The test coupons are being evaluated through both nondestructive and vibratory dampening testing to ascertain the degree of damage. Also, sequential through-the-thickness polishing and microscopical evaluation is performed to determine the ongoing damage mechanisms, measure the crack density and crack size distribution. The effect of time at temperature (i.e. environmental stability) is considered by pre-exposing selected specimens to high temperature for an appropriate time prior to testing. The evolving cyclic or time-dependent flaw population and distribution will be quantified, correlated to the nondestructive evaluation (NDE) and used in the analytical modeling. Further cyclic and monotonic data and other material properties of the selected CMC will be obtained by testing and supplemented by literature search where possible. The life prediction code will be validated through subcomponent cyclic and monotonic testing of complex geometries such as bolt holes or notches at appropriate test conditions.

Over the past year LeRC personnel have tested DuPont Lanxide C/SiC 0/90 plain-weave laminate coupon specimens. The tests conducted were elevated temperature tensile, creep, and fatigue tests. Test temperatures were 842 °F, 1,022 °F, and 1,200 °F. Stiffness data was monitored and stored throughout the tests. NDE inspec-

tions were performed on selected specimens which were subjected to interrupted testing and repeated inspection. Also, the fractography of failed specimens was initiated. Initial findings show that failure appears to be driven by environmental degradation of carbon fibers for this material. Strength of this CMC degrades rapidly at both 1,022 °F and 1,200 °F. Very little strength degradation was shown at 842 °F which verifies the hypothesis that the ongoing material damage is primarily governed by the failure of the carbon fibers since it is known that the environmental degradation of these fibers becomes negligible below approximately 900 °F. Tests done under cyclic loading showed longer time to failure than creep specimens when tested under similar temperatures and stresses.

One NDE technique being used for these specimens consists of the determination of the specimen's natural frequency as a function of creep exposure. A 1,200 °F stress rupture test was periodically interrupted and the natural frequency of the specimen was measured in a specially designed rig. The test conditions duplicated a previously tested specimen so that the approximate stress rupture life of the specimen was known. The natural frequency measurements were obtained in the as-machined condition prior to the test, 10-, 25-, 50-, 90-, and 100-percent of the estimated life. The actual failure occurred at approximately 125 percent of the estimated life. A decrease in the natural frequency was observed in the early stages of the test. The decrease of the measured natural frequency continued throughout the test. This technique is currently considered cumbersome and time consuming, but it is highly sensitive in detecting the evolution of damage even in its early stages. Natural frequency measurements can be translated into a measurement of the dynamic modulus of the specimen. The degradation of the modulus, which appears to occur in the early stages of testing, can then be used in the analytical life prediction models.

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**Biographical Sketch:** Rene Ortega has been employed with MSFC's Structural Integrity Branch for 9 years as a structural analyst (AST, Structural Mechanics) where his primary responsibility has been fracture analysis, stress, and fatigue of liquid rocket engine components. Ortega received a B.S. degree in civil engineering and a B.S. degree in architectural engineering from the University of Miami. He also received a M.S. degree in mechanical engineering from the University of Alabama in Huntsville. 